

**Project Report for the**  
**Southern California Exotics**  
**Expedition 2000**  
**A Rapid Assessment Survey of**  
**Exotic Species in Sheltered**  
**Coastal Waters**

Prepared by

Andrew N. Cohen, San Francisco Estuary Institute, Oakland CA  
Leslie H. Harris, Los Angeles County Museum of Natural History, Los Angeles CA  
Brian L. Bingham, Western Washington University, Bellingham WA  
James T. Carlton, Williams College-Mystic Seaport Maritime Studies Program, Mystic CT  
John W. Chapman, Hatfeld Marine Science Center, Oregon State University, Newport OR  
Charles C. Lambert, University of Washington, Friday Harbor WA  
Gretchen Lambert, University of Washington, Friday Harbor WA  
John C. Ljubenkov, Dancing Coyote Ranch Environmental, Pauma Valley CA  
Steven N. Murray, California State University, Fullerton CA  
Linda C. Rao, State Water Resources Control Board, Sacramento CA  
Kathleen Reardon, Island Institute, Rockland ME  
Evangelina Schwindt, Universidad Nacional de Mar del Plata, Mar del Plata, Argentina

For the

California Department of Fish and Game, Sacramento CA  
State Water Resources Control Board, Sacramento CA  
National Fish and Wildlife Foundation, San Francisco CA

January, 2002

## Executive Summary

In recent decades, the world has witnessed an array of harmful invasions by exotic marine and freshwater organisms. To provide the public and policymakers with better information on the status of exotic species in Southern California waters, the California Department of Fish and Game and the California State Water Resources Control Board, with supplemental funding from the National Fish and Wildlife Foundation, commissioned a Rapid Assessment Survey of selected sheltered waters between San Diego and Oxnard in the summer of 2000. The primary objective of the survey was to assess the status of exotic invasions within certain habitat types in the region. Secondary objectives included obtaining data for comparisons between habitats and regions and for comparisons with past surveys; obtaining baseline data for future assessments of changes in invasion status and the effectiveness of prevention or control efforts; detecting new invasions and documenting significant range extensions; and identifying new species.

## Methods

A team of taxonomic experts was assembled to sample and identify organisms at a number of sites within the region. Participants included staff and faculty from Western Washington University, Oregon State University/Hatfield Marine Science Center, San Francisco Estuary Institute, California State University at Fullerton, Los Angeles County Museum of Natural History, San Diego Ocean Monitoring Laboratory, California State Water Resources Control Board and the Williams College/Mystic Seaport Maritime Studies Program; and students from California State University at Fullerton, Williams College/Mystic Seaport Maritime Studies Program and Universidad Nacional de Mar del Plata. Twenty-two primary sampling sites and three secondary sites (where the collecting effort was less intensive) were selected to represent the three major commercial port areas in southern California (San Diego, Los Angeles/Long Beach and Port Hueneme), important marina areas and lagoon sites. Sampling was primarily of dock fouling along with adjacent soft-bottom benthos, nearby intertidal sites, and selected subtidal lagoon habitats. Sampling was conducted by a variety of manual techniques. Field identification of specimens was followed by examination of live sampled material in the laboratory by the expedition team and identification to lowest possible taxon. Laboratory work was conducted at the Los Angeles County Museum of Natural History (Polychaete Collection) and the San Diego Ocean Monitoring Laboratory, with followup work at participants' home institutions. Representative voucher collections were deposited with the Los Angeles County Museum of Natural History.

## Results

Salinities at most sites ranged from 31.5 to 36.5 psu, with one lower salinity site (San Dieguito Lagoon at 18.5 psu). Surface water temperatures ranged from 19.5 to 27°C, and were generally lower at the higher latitudes. The expedition collected 67 species that have been identified as exotic (Tables ES-1). Sixty-five of these species were found on floating piers and associated structures, which were sampled at a total of 21 sites; 20 species were found on fixed subtidal structures or shallow subtidal bottom in sampling at 5 sites; and 14 species were collected in benthic grabs at 13 sites. One exotic species, the Atlantic ribbed mussel *Geukensia demissa*, was

collected at the single intertidal beach site (Colorado Lagoon), and was not collected in any of the other habitats. One exotic species, the barnacle *Balanus amphitrite*, was collected at 2 of the 5 sites where barnacles were collected from intertidal pilings, and was also collected from floats or subtidal structures at some sites.

**Table ES-1. Summary data on exotic species collected**

Habitat sampled	Floats	Subtidal	Benthic	Beach	Piling	All
Number of sites sampled	21	5	14	1	5	25
Number of primary sites sampled	20	3	13	1	5	22
Number of species collected	65	20	13	1	1	67
Average species collected/site	16.2	5.2	1.8	1	0.4	15.2
Average species collected/primary site	16.7	6.3	1.9	1	0.4	16.7

The largest numbers of exotic species were found on floating piers, with an average of 16.7 exotic species collected at each primary site and a range of 10-22 exotic species per primary site. Collections taken from fixed subtidal structures or subtidal bottom at three primary sites averaged 2.1 and ranged from 1-12 exotic species per site (though the collection effort at the site where only one exotic species was collected was very limited). An average of 1.9 exotic species were collected in each benthic grab at 13 primary sites, with a range of 0-7 species per site. One exotic species was collected at the single intertidal beach site sampled. One exotic species was collected at 2 of the intertidal piling sites, for an average of 0.4 exotic species per piling site. Combining all habitats sampled, the number of exotic species collected ranged from 6 to 22 per primary site. There was no trend in the number of exotic species collected at primary sites relative to latitude, salinity or temperature.

The exotic organisms collected included representatives of seven high-level taxonomic groups. Sea squirts, crustaceans, bivalves and polychaetes were especially widespread (Table ES-2). Most of the exotic organisms collected are native to the northwestern Pacific, primarily the region including Japan, Korea and northern China. Another substantial group of organisms come from the North Atlantic, especially the northwestern Atlantic, with a smaller group from the southwestern Pacific (mainly Australia and New Zealand) and Indian Ocean.

**Table ES-2. Exotic organisms collected: diversity and frequency by higher taxonomic groups**

Taxon	Exotic species collected	Sites where collected
Macroalgae (seaweeds)	3	5
Cnidaria (anemones, etc.)	2	7
Annelida (polychaete worms)	10	18
Mollusca (bivalves, snails, etc.)	5	18
Arthropoda (crustaceans, etc.)	26	22
Bryozoa	6	12
Urochordata (sea squirts)	15	23
Total	67	24

For the exotic species collected on the expedition, the number of initial collection records for both the Pacific Coast and in southern California are greatest in the decades of the 1940s and the 1990s. It is not known whether these spikes result from stronger transport vectors during those periods (such as an increase in World War II-related military vessel traffic in the 1940s and an increase in commercial shipping and ballast water discharges from China, Japan and Korea in the 1990s), or whether they simply reflect greater collecting effort during those periods.

Transport as fouling organisms attached to the hulls of ships, or as wood-boring (or associated crevice-occupying) organisms in the hulls of wooden ships, is a possible vector for the transport of two-thirds of the exotic species collected by the expedition; ballast water discharges are a possible vector for over two-fifths of the species; and historic imports of Atlantic and Japanese oysters for commercial aquaculture are each a possible vector for about a tenth of the species.

## **Contents**

Introduction .....	1
Methods .....	2
Results .....	4
Literature Cited .....	19

## **Tables**

1 Sampling sites .....	3
2 Salinity, temperature and depth of benthic grab .....	4
3 Summary data on exotic species collected .....	5
4 Number of exotic species collected, by habitat and site .....	6
5 Exotic organisms collected: diversity and frequency by higher taxonomic groups ..	8
6 Exotic species collected, by sampling site .....	9
7 Origins, earliest records and mechanisms of introduction .....	13

## **Figures**

1 Variation of temperature with latitude .....	5
2 The number of exotic species collected at floating piers vs. latitude .....	7
3 The number of exotic species collected at floating piers vs. salinity .....	7
4 The number of exotic species collected at floating piers vs. temperature .....	8
5 Exotic species by native ranges .....	15
6 Exotic species by date of first Pacific Coast record .....	16
7 Exotic species by date of first Southern California record .....	16
8 Exotic species by possible mechanisms of transport to the Pacific Coast .....	17

## **Appendices**

1 List of participants .....	21
2 Expedition schedule .....	22
3 Recent name changes for some species mentioned in this report .....	23
4 List of Species collected and locations where found .....	CD
5 List of Cryptogenic Species and locations where found .....	CD

## Introduction

In recent decades, the world has witnessed an array of harmful invasions by exotic marine and freshwater organisms. These include:

- The Atlantic comb jelly, *Mnemiopsis leidyi*, which was introduced into the Black and Azov Seas in the early 1980s. It became phenomenally abundant and consumed much of the seas' crustacean zooplankton, contributing to the decline of the region's anchovy and sprat fisheries and of the fishing fleets of six nations that depended on them (Travis 1993).
- European zebra mussels, *Dreissena polymorpha*, which appeared in the Great Lakes in the late 1980s. Zebra mussels have become a massive nuisance, causing millions of dollars of damage primarily by blocking the water intake systems of cities, factories and power plants. Within a few years' time, the mussels had spread across much of North America, from Canada to New Orleans and from the Hudson River to Oklahoma (Nalepa and Schloesser 1993)
- Toxic red tides that have appeared in many parts of the world, and which were caused in some cases by dinoflagellates introduced by ballast water or shellfish imports for aquaculture (Hallegraeff *et al.* 1989; Hallegraeff and Bolch 1991). Human neurotoxins produced by the dinoflagellates accumulate in clams or mussels, sickening and occasionally killing people that eat them. During a red tide outbreak in New Zealand, people walking along the shore became ill from airborne toxins (O'Hara 1993).
- The cholera-causing bacterium *Vibrio cholerae*. In 1991, when the South American epidemic strain of this bacteria was discovered in oysters and fish in Mobile Bay, Alabama, the U.S. Food and Drug Administration sampled ships arriving from South America and found the same strain of cholera in the ballast water of a third of them (U.S. *Federal Register* 1991; McCarthy and Khambaty 1994). Some medical researchers believe that ballast water discharges were responsible for initially introducing the cholera strain into South America (Ditchfield 1993; Epstein *et al.* 1993), triggering an epidemic that resulted in at least a million cases and ten thousand deaths (Tauxe 1995).

These and other well-publicized aquatic invasions, including the introduction to the Pacific Coast of the European green crab *Carcinus maenas* (Cohen *et al.* 1995) and the Chinese mitten crab *Eriocheir sinensis* (Cohen and Carlton 1997), have led to increasing public concern about the status and impacts of non-native species.

To provide the public and policymakers with better information on the status of exotic species in Southern California waters, the California Department of Fish and Game and the California State Water Resources Control Board, with supplemental funding from the National Fish and Wildlife Foundation, commissioned a Rapid Assessment Survey of selected sheltered waters between San Diego and Oxnard in the summer of 2000. This survey was the seventh in a series of Rapid Assessment Surveys for exotic marine organisms on the Pacific Coast. Four surveys were conducted in San Francisco Bay in 1993, 1994, 1996 and 1997; a survey of Puget Sound was conducted in 1998; and a survey of three regions in Washington state (in central Puget Sound, southern Puget Sound, and Willapa Bay) was conducted in the spring of 2000. The primary goal of each survey was to provide general information on the extent of biological invasions within a region in terms of the number and distribution of non-native species that are present. To this end, multi-institutional teams of taxonomic experts were assembled to quickly sample and identify a broad suite of organisms at a number of sites

within the region. Participants in the current study included staff and faculty from Western Washington University, Oregon State University/Hatfield Marine Science Center, San Francisco Estuary Institute, California State University at Fullerton, Los Angeles County Museum of Natural History, San Diego Ocean Monitoring Laboratory, California State Water Resources Control Board and the Williams College/Mystic Seaport Maritime Studies Program; and students from California State University at Fullerton, Williams College/Mystic Seaport Maritime Studies Program and Universidad Nacional de Mar del Plata.

## Methods

As in past surveys, our primary objective was to conduct a rapid assessment of the status of exotic invasions within defined regions and habitat types through non-quantitative or semi-quantitative census methods. Secondary objectives were to obtain data for comparisons between habitats and regions, and for comparisons with past surveys; to obtain baseline data for future assessments of changes in invasion status and the effectiveness of prevention or control efforts; to detect new invasions and document significant range extensions; and to identify new species.

Twenty-two primary sampling sites and three secondary sites were selected to represent the three major commercial port areas in southern California (San Diego, Los Angeles/Long Beach, and Port Hueneme), important marina areas and lagoon sites (Table 1). We mainly sampled dock fouling (organisms growing on the sides and undersides of floating piers and associated floats, bumpers, tires, ropes, etc.) along with soft-bottom benthos adjacent to these sites, some nearby intertidal sites, and selected subtidal lagoon habitats. Primary sampling sites were selected during a reconnaissance trip in June 2000. Three secondary sites, all representing highly modified or artificial lagoon environments, were added during the survey and sampled briefly by a subset of the expedition team. The summary data on number of exotic species collected are provided for both primary sites alone and for all sites (in Table 3), and the data on number of exotic species collected versus latitude, salinity and temperature variables are provided for primary sites alone (in Figures 2-4).

Near surface (0-0.3 m) salinity and temperature were measured at all primary sampling sites, usually using two refractometers and two thermometers and reported as the average of the two readings. Salinity measurements are presented in this report in Practical Salinity Units (psu), which are comparable to parts per thousand (ppt). Latitude and longitude were measured with a hand-held GPS unit.

At each primary sampling site samples were collected by the expedition team during a period of approximately one hour, using a variety of manual techniques. Tools included hand scrapers, a custom-made long-handled scraper with a steel mesh net, and sieves. Benthic (bottom) samples were taken with an Ekman grab, washed onto a 0.5 mm sieve and sorted by eye to major taxonomic group on site. Field identification of specimens was followed by examination of live sampled material in the laboratory by the expedition's team of taxonomic experts, and identification to lowest possible taxon.<sup>1</sup>

---

<sup>1</sup> Molecular genetic analyses are needed to reliably distinguish among bay mussels in the *Mytilus edulis*-complex. Molecular analyses of mussels in this complex in California waters south of Monterey Bay have mainly found *M. galloprovincialis* (McDonald and Koehn 1988; Sarver and Foltz 1993), though there is evidence of small numbers of *M. trossulus* or hybrids (Sarver and Foltz 1993; Suchanek *et al.* 1997) and of mitochondrial introgression of *M. trossulus* genes (Geller 1994). In this study we assumed that any collections of *M. edulis*-complex mussels in southern California included at least some *M. galloprovincialis*.

A one-liter representative voucher collection was obtained from each main sampling site, plus additional samples of material of interest. The samples were kept on ice in insulated coolers until examination in the laboratory. Laboratory work was conducted at the Los Angeles County Museum of Natural History and the San Diego Ocean Monitoring Laboratory. Organisms were identified by expedition team members, with some material retained by individuals for further study at their home institution, and other material prepared for shipment to specialists for additional work. Specimens of Pacific oysters (*Crassostrea gigas*) were preserved in 95% ethanol for future DNA analysis to assess their probable transport mechanisms. After examination was completed, voucher samples and most of the other specimens were fixed in 10% formalin and transferred to 70% ethanol. The voucher collections were deposited with the Los Angeles County Museum of Natural History.

Additional information on the participants and the survey schedule is provided in the Appendix.

**Table 1. Sampling sites**

Site number	Site name	Location	County	GPS latitude	GPS longitude
SCX-01	Chula Vista Boat Ramp	San Diego Bay	San Diego	32° 37' 16"	117° 06' 11"
SCX-02	Fiddler's Cove	San Diego Bay	San Diego	32° 39' 07"	117° 08' 58"
SCX-03	Shelter Island	San Diego Bay	San Diego	32° 42' 36"	117° 14' 03"
SCX-04	Seaforth Landing	Mission Bay	San Diego	32° 45' 52"	117° 14' 17"
SCX-05	San Dieguito Lagoon		San Diego	32° 58' 04"	117° 15' 35"
SCX-06	Snug Harbor Marina	Agua Hedionda Lagoon	San Diego	33° 08' 52"	117° 19' 56"
SCX-07	Oceanside Harbor		San Diego	33° 12' 34"	117° 23' 41"
SCX-08	Huntington Harbor Yacht Club	Anaheim Bay	Orange	33° 42' 45"	118° 03' 40"
SCX-09	Long Beach Yacht Club	Alamitos Bay	Los Angeles	33° 45' 13"	118° 16' 51"
SCX-10	Colorado Lagoon	Alamitos Bay	Los Angeles	33° 46' 16"	118° 08' 05"
SCX-11	Long Beach Downtown Marina		Los Angeles	33° 45' 29"	118° 11' 22"
SCX-12	Pilots' Dock at Pier F	Long Beach Harbor	Los Angeles	33° 44' 50"	118° 12' 56"
SCX-13	Impound Marina	Long Beach Harbor	Los Angeles	33° 45' 50"	118° 14' 40"
SCX-14	Newmarks Yacht Harbor	Los Angeles Harbor	Los Angeles	33° 45' 52"	118° 14' 59"
SCX-15	Island Yacht Anchorage	Los Angeles Harbor	Los Angeles	33° 46' 22"	118° 14' 52"
SCX-16	Watchorn Basin	Los Angeles Harbor	Los Angeles	33° 43' 13"	118° 16' 35"
SCX-17	Cabrillo Beach Boat Ramp	Los Angeles Harbor	Los Angeles	33° 42' 47"	118° 16' 06"
SCX-18	King Harbor		Los Angeles	33° 50' 47"	118° 23' 49"
SCX-19	Marina del Rey		Los Angeles	33° 58' 20"	118° 27' 08"
SCX-20	Port Hueneme Sportfishing	Port of Hueneme	Ventura	34° 08' 53"	119° 12' 07"
SCX-21	Jack's Landing	Channel Islands Harbor	Ventura	34° 09' 49"	119° 13' 22"
SCX-22	Anacapa Isle Marina	Channel Islands Harbor	Ventura	34° 10' 23"	119° 13' 37"
SS-A	Huntington Harbor - Back Lagoon	Anaheim Bay	Orange	33° 43' 43"	118° 03' 36"
SS-B	Rainbow Lagoon		Los Angeles	33° 45' 47"	118° 11' 29"
SS-C	Venice Lagoon		Los Angeles	not recorded	not recorded

## Results

The Expedition sampled at 22 primary and 3 secondary sites from Oxnard to San Diego. The salinities at nearly all these sites were very close, mainly ranging from 34 to 36.5 psu (Table 2). Island Yacht Anchorage, at the mouth of the Dominguez Channel at the back end of Los Angeles Harbor, was slightly lower at 31.5 psu. San Dieguito Lagoon with a salinity of 18.5 psu was the only sampled site with significantly lower salinity than is found in the near-shore ocean. Surface water temperatures ranged from 19.5 to 27°C (Table 2), being generally lower at higher latitudes (Fig. 1).

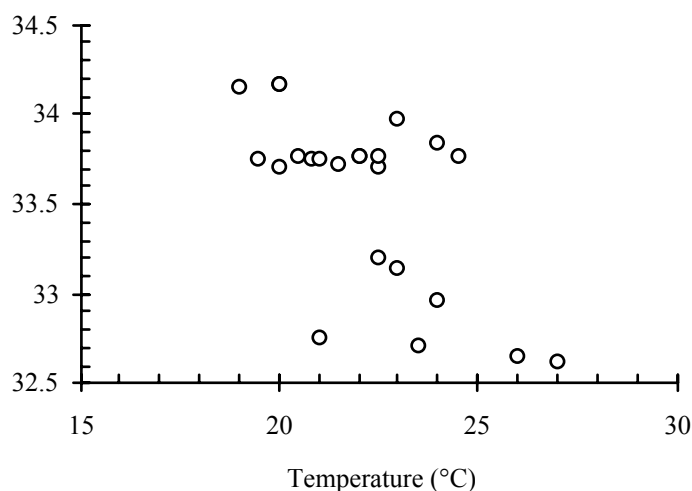
**Table 2. Salinity, temperature and depth of benthic grab**

Site number	Site name	Salinity (PSU)	Temperature (°C)	Grab depth (m)
SCX-01	Chula Vista Boat Ramp	36.5	27	—
SCX-02	Fiddler's Cove	35.5	26	—
SCX-03	Shelter Island	35.5	23.5	6
SCX-04	Seaforth Landing	34.5	21	—
SCX-05	San Dieguito Lagoon	18.5	24	—
SCX-06	Snug Harbor Marina	35	23	—
SCX-07	Oceanside Harbor	34.5	22.5	6.5
SCX-08	Huntington Harbor Yacht Club	34	22.5	6.5
SCX-09	Long Beach Yacht Club	34	20.8	3
SCX-10	Colorado Lagoon	34	22	—
SCX-11	Long Beach Downtown Marina	35	21	—
SCX-12	Pilots' Dock at Pier F	34.5	19.5	9
SCX-13	Impound Marina	34.5	20.5	5.5
SCX-14	Newmarks Yacht Harbor	34	22	—
SCX-15	Island Yacht Anchorage	31.5	22.5	—
SCX-16	Watchorn Basin	34.5	21.5	2
SCX-17	Cabrillo Beach Boat Ramp	35	20	1.5
SCX-18	King Harbor	34.5	24	7.5
SCX-19	Marina del Rey	34.5	23	5
SCX-20	Port Hueneme Sportfishing	35	19	6.5
SCX-21	Jack's Landing	35.5	20	5
SCX-22	Anacapa Isle Marina	35	20	4
SS-A	Huntington Harbor - Back Lagoon	not recorded	not recorded	not recorded
SS-B	Rainbow Lagoon	35	24.5	—
SS-C	Venice Lagoon	36.5	not recorded	—

Dock fouling was sampled at the 20 of the 22 primary sites where there were floating piers. At San Dieguito Lagoon (Site 5) and Colorado Lagoon (Site 10) there were no floating piers, and organisms were collected instead from bridge and supports and structures and the adjacent bottom. Benthic grabs were taken at 13 primary and one secondary site (the back lagoon at Huntington Harbor, Secondary Site A), at depths ranging from 1.5 to 9 m (Table 2). Collections of barnacles from the intertidal reaches of pilings were made at five of the primary sites, intertidal molluscs and mollusc shells were

collected from the shore of Colorado Lagoon in Anaheim Bay, and molluscs were collected from shallow subtidal rocks at Island Yacht Anchorage (Site 15) in Los Angeles Harbor. Organisms were collected from shallow bottom and structures (walls, bridge supports) at two of the secondary sites, the Venice Lagoon and Rainbow Lagoon (Secondary Sites C and B, respectively). Floating piers at the remaining secondary site, the back lagoon in Huntington Harbor, were examined for ascidians only.

**Figure 1. Variation of temperature with latitude**



## Exotic Species Collected

The Expedition collected 67 species that have been identified as exotic (Tables 3 and 5). Sixty-five of these species were found on floating piers and associated structures, which were sampled at a total of 21 sites; 20 species were found on fixed subtidal structures or shallow subtidal bottom in sampling at 5 sites; and 14 species were collected in benthic grabs at 13 sites. One exotic species, the Atlantic ribbed mussel *Geukensia demissa*, was collected at the single intertidal beach site (Colorado Lagoon, Site 10), and was not collected in any of the other habitats. One exotic species, the barnacle *Balanus amphitrite*, was collected at 2 of the 5 sites where barnacles were collected from intertidal pilings, and was also collected from floats or subtidal structures at some sites.

**Table 3. Summary data on exotic species collected**

Habitat sampled	Floats	Subtidal	Benthic	Beach	Piling	All
Number of sites sampled	21	5	14	1	5	25
Number of primary sites sampled	20	3	13	1	5	22
Number of species collected	65	20	13	1	1	67
Average species collected/site	16.2	5.2	1.8	1	0.4	15.2
Average species collected/primary site	16.7	6.3	1.9	1	0.4	16.7

The largest numbers of exotic species were found in the collections made on floating piers, with an average of 16.7 exotic species collected at each primary site and a range of 10-22 exotic species per primary site (Tables 3 and 4). Collections taken from fixed subtidal structures or subtidal bottom at three primary sites averaged 2.1 and ranged from 1-12 exotic species, but the collection effort at Site 15 (Island Yacht Anchorage), where only one exotic species was collected, was very limited. An average of 1.9 exotic species were collected in each benthic grab at 13 primary sites, with a range of 0-7 species. One exotic species was collected at the single intertidal beach site sample; and one exotic species was collected at 2 of the intertidal piling sites, for an average of 0.4 exotic species per piling site.

**Table 4. Number of exotic species collected, by habitat and site**

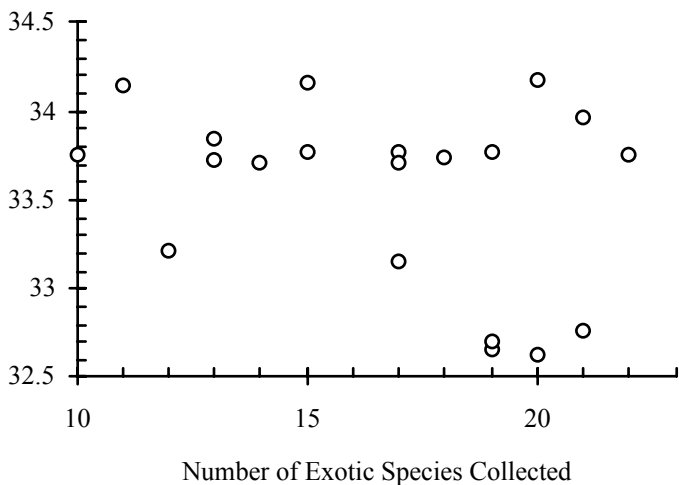
FLOATING PIERS AND ASSOCIATED STRUCTURES														
Site number	1	2	3	4	6	7	8	9	11	12	13	14	15	16
Species collected/site	20	19	19	21	17	12	14	22	10	18	15	19	17	13
Site number	17	18	19	20	21	22	A							
Species collected/site	17	13	21	11	15	20	7							
SUBTIDAL FIXED STRUCTURES AND SHALLOW BOTTOM														
Site number	5	10	15	B	C									
Species collected/site	6	12	1	7	0									
BENTHIC GRAB														
Site number	3	7	8	9	12	13	16	17	18	19	20	21	22	A
Species collected/site	0	0	1	0	2	2	3	2	1	0	5	7	2	0
INTERTIDAL BEACH														
Site number	10													
Species collected/site	1													
INTERTIDAL PILINGS														
Site number	6	7	9	10	12									
Species collected/site	0	0	0	1	1									
ALL HABITATS SAMPLED														
Site number	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Species collected/site	20	19	19	21	6	17	12	15	22	13	10	20	16	19
Site number	15	16	17	18	19	20	21	22	A	B	C			
Species collected/site	18	15	17	14	21	13	18	22	7	7	0			

Combining all habitats sampled, the largest number of exotic species were collected at Long Beach Yacht Club in Alamitos Bay and at the Anacapa Isle Marina in Channel Islands Harbor (Sites 9 and 22), with 22 collected at each. These sites also had the largest number of exotic species collected from floating piers, but few from benthic grabs (Table 4). Among primary sites, the smallest number of

exotic species (6) was collected at the San Dieguito Lagoon (Site 5), where there were no floating piers to sample. Colorado Lagoon in Alamitos Bay (Site 10), which also had no floating piers, had an intermediate number of exotic species (13). The largest number of species collected from benthic grabs occurred at two of the northernmost sites, 7 species at Jack's Landing in Channel Islands Harbor (Site 21) and 5 species at the Port Hueneme Sportfishing docks in the Port of Hueneme (Site 20).

There was no trend in the number of exotic species collected at primary sites relative to latitude, salinity or temperature. Figures 2, 3 and 4 show the data for organisms collected at floating piers and associated structures.

**Figure 2. The number of exotic species collected at floating piers vs. latitude**



**Figure 3. The number of exotic species collected at floating piers vs. salinity**

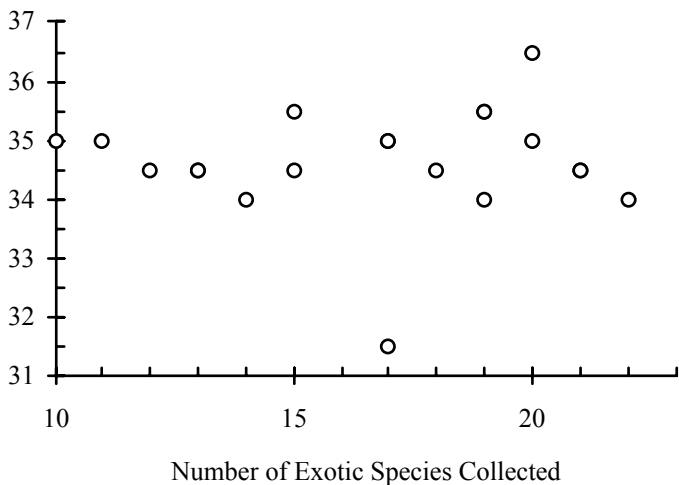
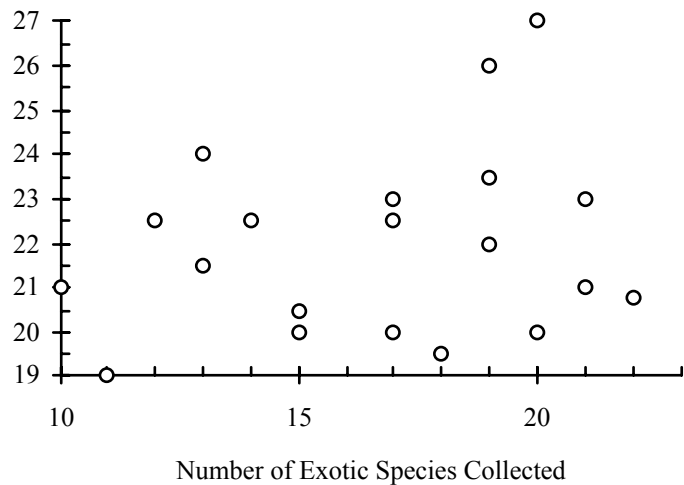


Figure 4. The number of exotic species collected at floating piers vs. temperature



The exotic organisms collected included representatives of seven high-level taxonomic groups (Table 5). Sea squirts, arthropods (mainly crustaceans), molluscs (all of them bivalves), and annelids (all of them polychaetes) were especially widespread, being collected in at least three-quarters of the sites where exotic organisms were found.

Table 5. Exotic organisms collected: diversity and frequency by higher taxonomic groups

Taxon	Exotic species collected	Sites where collected
Macroalgae (seaweeds)	3	5
Cnidaria (anemones, etc.)	2	7
Annelida (polychaete worms)	10	18
Mollusca (bivalves, snails, etc.)	5	18
Arthropoda (crustaceans, etc.)	26	22
Bryozoa	6	12
Urochordata (sea squirts)	15	23
Total	67	24

The most widely-occurring species were the sea squirts *Ciona intestinalis* (collected at 21 sites), *Styela clava* and *Styela plicata* (each collected at 20 sites), and *Botrylloides violaceus* (17 sites); the mussel *Mytilus galloprovincialis* (17 sites); and the sea squirt *Bottyllus schlosseri* (16 sites). These findings are consistent with previous reports of the common occurrence of exotic sea squirts in southern California (Lambert and Lambert 1998).

Table 6. Exotic species collected, by sampling site

(page 1 of 4)

Species	Sampling sites													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<u>Phaeophyta</u>														
<i>Sargassum muticum</i>		x										x	x	
<i>Undaria pinnatifida</i>														
<u>Rhodophyta</u>														
<i>Lomentaria hakodatensis</i>		x											x	
<u>Cnidaria: Anthozoa</u>														
<i>Bunodeopsis</i> sp. A					x	x								
<i>Diadumene franciscana</i>						x						x		
<u>Annelida: Polychaeta</u>														
<i>Amblyosyllis speciosa</i>				x									x	
<i>Bispira</i> sp. A													x	
<i>Demonax</i> sp. A	x							x	x		x			
<i>Ficopomatus enigmaticus</i>														
<i>Hydroides dirampa</i>				x										
<i>Hydroides elegans</i>										x	x			
<i>Myrianida pachycera</i>	x		x						x			x		
<i>Nicolea</i> sp. A			x	x		x		x	x		x	x	x	x
<i>Pseudopolydora paucibranchiata</i>											x		x	
<i>Typosyllis nipponica</i>													x	x
<u>Mollusca: Bivalvia</u>														
<i>Crassostrea gigas</i>														
<i>Geukensia demissa</i>										x				
<i>Musculista senhousia</i>	x													
<i>Mytilus galloprovincialis</i>	x			x	x	x			x	x		x		x
<i>Teredo bartschi</i>													x	
<u>Arthropoda: Pycnogonida</u>														
<i>Ammothella hilgendorfi</i>														
<u>Arthropoda: Crustacea: Cirripedia</u>														
<i>Balanus amphitrite</i>	x	x								x	x	x		
<i>Balanus eburneus</i>										x				
<u>Arthropoda: Crustacea: Tanaidacea</u>														
? <i>Sinelobus stanfordi</i>	x													
<u>Arthropoda: Crustacea: Isopoda</u>														
<i>Ianiropsis tridens</i>						x								
<i>Limnoria tripunctata</i>													x	
<i>Paranthura japonica</i>	x	x	x	x		x	x	x	x	x		x		
<i>Sphaeroma quoyanum</i>										x				
<u>Arthropoda: Crustacea: Amphipoda: Gammaridea</u>														
<i>Ampithoe valida</i>														
<i>Aoriodes secunda</i>			x	x		x		x	x			x		x
<i>Chelura terebrans</i>												x	x	
<i>Corophium acherusicum</i>						x	x		x	x				

Table 6. Exotic species collected, by sampling site

(page 2 of 4)

Species	Sampling sites											No. of sites /species
	15	16	17	18	19	20	21	22	A	B	C	
<u>Phaeophyta</u>												
<i>Sargassum muticum</i>												3
<i>Undaria pinnatifida</i>			x									1
<u>Rhodophyta</u>												
<i>Lomentaria hakodatensis</i>							x					3
<u>Cnidaria: Anthozoa</u>												
<i>Bunodeopsis</i> sp. A												2
<i>Diadumene franciscana</i>	x	x			x			x				6
<u>Annelida: Polychaeta</u>												
<i>Amblyosyllis speciosa</i>												2
<i>Bispira</i> sp. A								x				2
<i>Demonax</i> sp. A					x							5
<i>Ficopomatus enigmaticus</i>	x											1
<i>Hydroides dirampa</i>												1
<i>Hydroides elegans</i>												2
<i>Myrianida pachycera</i>				x	x			x				7
<i>Nicolea</i> sp. A		x	x						x			12
<i>Pseudopolydora paucibranchiata</i>		x		x								4
<i>Typosyllis nipponica</i>		x	x			x		x				6
<u>Mollusca: Bivalvia</u>												
<i>Crassostrea gigas</i>	x											1
<i>Geukensia demissa</i>												1
<i>Musculista senhousia</i>										x		2
<i>Mytilus galloprovincialis</i>	x	x	x	x	x	x	x	x		x		17
<i>Teredo bartschi</i>												1
<u>Arthropoda: Pycnogonida</u>												
<i>Ammothella hilgendorfi</i>			x									1
<u>Arthropoda: Crustacea: Cirripedia</u>												
<i>Balanus amphitrite</i>		x			x							7
<i>Balanus eburneus</i>												1
<u>Arthropoda: Crustacea: Tanaidacea</u>												
<i>?Sinelobus stanfordi</i>												1
<u>Arthropoda: Crustacea: Isopoda</u>												
<i>Ianiropsis tridens</i>	x					x	x					4
<i>Limnoria tripunctata</i>												1
<i>Paranthura japonica</i>	x			x	x	x		x				15
<i>Sphaeroma quoyanum</i>	x											2
<u>Arthropoda: Crustacea: Amphipoda: Gammaridea</u>												
<i>Ampithoe valida</i>							x					1
<i>Aoriodes secunda</i>	x				x	x	x	x				12
<i>Chelura terebrans</i>												2
<i>Corophium acherusicum</i>				x	x	x	x	x				9

Table 6. Exotic species collected, by sampling site

(page 3 of 4)

Species	Sampling sites													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<u>Arthropoda: Crustacea: Amphipoda: Gammaridea - continued</u>														
<i>Corophium insidiosum</i>					x	x								
<i>Elasmopus rapax</i>	x		x	x	x	x	x	x	x	x		x		
<i>Erichthonius brasiliensis</i>	x	x	x	x	x	x	x		x			x		
<i>Grandidierella japonica</i>														
<i>Jassa marmorata</i>									x			x		x
<i>Leucothoe alata</i>	x	x	x	x		x	x	x				x		x
<i>Liljeborgia</i> sp.		x	x	x		x	x		x			x		x
<i>Melita</i> sp.								x						x
<i>Metopella</i> sp.									x					
<i>Paradexamine</i> cf. <i>churinga</i>								x						
<i>Stenothoe valida</i>														
<u>Arthropoda: Crustacea: Amphipoda: Caprellidea</u>														
<i>Caprella mutica</i>												x		x
<i>Caprella simia</i>														
<u>Arthropoda: Crustacea: Decapoda</u>														
<i>Palaemon macrodactylus</i>					x									
<u>Bryozoa: Chenostomata</u>														
<i>Zoobotryon verticillatum</i>														x
<u>Bryozoa: Cheilostomata</u>														
<i>Bugula flabellata</i>												x		
<i>Bugula neritina</i>														
<i>Cryptosula pallasiana</i>														x
<i>Watersipora arcuata</i>										x				
<i>Watersipora</i> ? <i>subtorquata</i>	x			x		x								x
<u>Urochordata</u>														
<i>Ascidia</i> sp. A	x	x							x					
<i>Ascidia zara</i>			x	x				x						x
<i>Botrylloides violaceus</i>	x	x	x	x				x	x				x	x
<i>Botryllus firmus</i>			x	x										
<i>Botryllus schlosseri</i>		x	x	x		x	x	x	x		x		x	
<i>Botryllus</i> sp. A		x					x							
<i>Ciona intestinalis</i>	x	x	x	x				x	x	x	x	x	x	x
<i>Ciona savignyi</i>	x	x	x	x				x	x					x
<i>Microcosmus squamiger</i>	x	x		x		x	x	x	x			x		x
<i>Molgula manhattensis</i>										x	x			
<i>Polyandrocarpa zorritensis</i>	x	x	x	x			x		x				x	
<i>Styela canopus</i>	x	x	x						x					
<i>Styela clava</i>	x	x	x	x		x	x		x		x	x	x	x
<i>Styela plicata</i>	x	x	x	x			x	x	x	x	x	x	x	x
<i>Symplegma reptans</i>		x	x											
Number of exotics/site	20	19	19	21	6	17	12	15	22	13	10	20	16	19

Table 6. Exotic species collected, by sampling site

(page 4 of 4)

Species	Sampling sites											No. of sites
	15	16	17	18	19	20	21	22	A	B	C	/species
<u>Arthropoda: Crustacea: Amphipoda: Gammaridea - continued</u>												
<i>Corophium insidiosum</i>												2
<i>Elasmopus rapax</i>				x	x		x	x				14
<i>Erichthonius brasiliensis</i>				x	x		x	x				13
<i>Grandidierella japonica</i>						x	x	x				3
<i>Jassa marmorata</i>							x					4
<i>Leucothoe alata</i>					x							10
<i>Liljeborgia</i> sp.					x							9
<i>Melita</i> sp.												2
<i>Metopella</i> sp.			x									2
<i>Paradexamine</i> cf. <i>churinga</i>	x		x		x		x					5
<i>Stenothoe valida</i>					x		x					2
<u>Arthropoda: Crustacea: Amphipoda: Caprellidea</u>												
<i>Caprella mutica</i>	x					x	x	x				6
<i>Caprella simia</i>	x											1
<u>Arthropoda: Crustacea: Decapoda</u>												
<i>Palaemon macrodactylus</i>												1
<u>Bryozoa: Chenostomata</u>												
<i>Zoobotryon verticillatum</i>		x								x		3
<u>Bryozoa: Cheilostomata</u>												
<i>Bugula flabellata</i>												1
<i>Bugula neritina</i>			x									1
<i>Cryptosula pallasiana</i>						x		x				3
<i>Watersipora arcuata</i>						x		x				3
<i>Watersipora ?subtorquata</i>		x	x		x							7
<u>Urochordata</u>												
<i>Ascidia</i> sp. A												3
<i>Ascidia zara</i>	x	x			x			x				8
<i>Botrylloides violaceus</i>	x	x	x	x	x	x	x	x	x			17
<i>Botryllus firmus</i>												2
<i>Botryllus schlosseri</i>		x	x	x	x		x	x	x			16
<i>Botryllus</i> sp. A												2
<i>Ciona intestinalis</i>	x	x	x	x	x	x	x	x	x	x		21
<i>Ciona savignyi</i>	x	x	x					x	x			12
<i>Microcosmus squamiger</i>			x	x				x	x	x		14
<i>Molgula manhattensis</i>	x									x		4
<i>Polyandrocarpa zorritensis</i>				x								8
<i>Styela canopus</i>												4
<i>Styela clava</i>	x	x	x	x	x	x	x	x	x			20
<i>Styela plicata</i>	x	x	x	x	x		x		x	x		20
<i>Symplegma reptans</i>			x									3
Number of exotics/site	18	15	17	14	21	13	18	22	7	7	0	

Most of the exotic organisms collected are native to the northwestern Pacific, primarily the region including Japan, Korea and northern China (Table 7 and Fig. 5). Another substantial group of

organisms come from the North Atlantic, especially the northwestern Atlantic, with a smaller group from the southwestern Pacific (mainly Australia and New Zealand) and Indian Ocean. One organism is native to the southeastern Pacific (the tunicate *Polyandrocarpa zorritensis*, reported from Peru), and none are native to the South Atlantic. These patterns of origin are generally consistent with the main shipping connections and historic sources of aquaculture stock for southern California.

Table 7. Origins, earliest records and mechanisms of introduction

(page 1 of 3)

Native ranges, dates of earliest record (planting, collection or report) on the Pacific Coast of North America, in California, and in Southern California (south of Point Conception), and possible initial mechanisms of introduction to the Pacific Coast are given. Much of this information is expanded and revised from Carlton (1979), Cohen and Carlton (1995), Cohen *et al.* (1998), Lambert and Lambert (1998), Mills *et al.* (2000) and Cohen *et al.* (2001), with additional information provided by L.H. Harris and J.W. Chapman. Earliest records consisting of written accounts that do not state the date of planting, collection or observation are preceded by the symbol "≤". Mechanisms given in parentheses indicate less likely mechanisms. Mechanisms are listed as:

SF - in ships' hull fouling or boring

OA - with shipments of Atlantic oysters

BW - in ships' ballast water or seawater systems

OJ - with shipments of Japanese oysters

Species	Native Range	First Pacific Coast Record	First Southern California Record	Mechanism of Introduction
<u>Phaeophyta</u>				
<i>Sargassum muticum</i>	NW Pacific	1944	1970	OJ
<i>Undaria pinnatifida</i>	NW Pacific	2000	2000	SF,(BW)
<u>Rhodophyta</u>				
<i>Lomentaria hakodatensis</i>	NW Pacific	1963?	1963?	?
<u>Cnidaria: Anthozoa</u>				
<i>Bunodeopsis</i> sp. A	not known	≈1985-87	1996	SF,BW
<i>Diadumene franciscana</i>	not known	1925-40	1977-78	SF,BW
<u>Annelida: Polychaeta</u>				
<i>Amblosyllis speciosa</i>	NW Pacific	2000?	2000?	?
<i>Bispira</i> sp.	not known	2000	2000	?
<i>Demonax</i> sp.	not known	2000?	2000?	?
<i>Ficopomatus enigmaticus</i>	not known	1920	2000	SF
<i>Hydroides dirampa</i>	NW Atlantic	1999	1999	
<i>Hydroides elegans</i>	Indo-Pacific	1931	1931	SF
<i>Myrianida pachycera</i>	SW Pacific	2000?	2000?	?
<i>Nicolea</i> sp. A	not known	2000?	2000?	?
<i>Pseudopolydora paucibranchiata</i>	Indo-Pacific	1950	1950	BW,SF,OJ
<i>Typosyllis nipponica</i>	NW Pacific	1997	2000?	BW,(SF)
<u>Mollusca: Bivalvia</u>				
<i>Crassostrea gigas</i>	NW Pacific	1875	1932	OJ,BW?
<i>Geukensia demissa</i>	NW Atlantic	1894	1940	OA
<i>Musculista senhousia</i>	Indo-Pacific	1924	1965	OJ
<i>Mytilus galloprovincialis</i>	NE Atlantic	1947	1947	BW,SF
<i>Teredo bartschi</i>	Indo-Pacific	≤1927	≤1927	SF

Table 7. Origins, earliest records and mechanisms of introduction

(page 2 of 3)

Species	Native Range	First Pacific Coast Record	First Southern California Record	Mechanism of Introduction
<u>Arthropoda: Pycnogonida</u>				
<i>Ammothella hilgendorfi</i>	NW Pacific	?	?	?
<u>Arthropoda: Crustacea: Cirripedia</u>				
<i>Balanus amphitrite</i>	Indian Ocean	1921	1921	SF
<i>Balanus eburneus</i>	NW Atlantic	1959	?	SF,BW
<u>Arthropoda: Crustacea: Tanaidacea</u>				
? <i>Sinelobus stanfordi</i>	not known	1943	2000?	SF,BW
<u>Arthropoda: Crustacea: Isopoda</u>				
<i>Ianiropsis tridens</i>	NW Pacific	?	2000	?
<i>Limnoria tripunctata</i>	not known	1875	1876	SF
<i>Paranthura japonica</i>	NW Pacific	1993	2000	BW,SF
<i>Sphaeroma quoyanum</i>	SW Pacific	1893	1927	SF
<u>Arthropoda: Crustacea: Amphipoda: Gammaridea</u>				
<i>Ampithoe valida</i>	NW Atlantic	1941	1942	BW,OA,SF
<i>Aoridae secunda</i>	NW Pacific	?	?	?
<i>Chelura terebrans</i>	not known	1948	1950	SF
<i>Corophium acherusicum</i>	N Atlantic	1905	1935	OA,SF
<i>Corophium insidiosum</i>	N Atlantic	1915	1949	OA,SF
<i>Elasmopus rapax</i>	not known	1938?	1952	SF,BW?
<i>Erichthonius brasiliensis</i>	not known	1943-45	1943-45	?
<i>Grandidierella japonica</i>	NW Pacific	1966	?	OJ,SF,BW
<i>Jassa marmorata</i>	NW Atlantic	1938	1950	SF,BW
<i>Leucothoe alata</i>	?	1977	?	SF,(OA.OJ)
<i>Liljeborgia</i> sp.	not known	?	?	?
<i>Melita</i> sp.	not known	1993	?	BW,SF
<i>Metopella</i> sp.	not known	?	?	?
<i>Paradexamine</i> cf. <i>churinga</i>	W Pacific?	1993	?	BW,SF
<i>Stenothoe valida</i>	not known	≤1941	1950-51	BW,SF
<u>Arthropoda: Crustacea: Amphipoda: Caprellidea</u>				
<i>Caprella mutica</i>	NW Pacific	1973-77	?	OJ,BW
<i>Caprella simia</i>	NW Pacific	?	?	?
<u>Arthropoda: Crustacea: Decapoda</u>				
<i>Palaemon macrodactylus</i>	NW Pacific	1957	1962	BW
<u>Bryozoa: Chenostomata</u>				
<i>Zoobotryon verticillatum</i>	not known	1905	1905	SF
<u>Bryozoa: Cheilostomata</u>				
<i>Bugula flabellata</i>	?	1905	1905	SF
<i>Bugula neritina</i>	not known	≤1905	?	SF, (OA)
<i>Cryptosula pallasiana</i>	N Atlantic	1943-44	1943-44	OA,SF
<i>Watersipora arcuata</i>	not known	1961	1964	SF
<i>Watersipora</i> ? <i>subtorquata</i>	not known	1961	1963	SF

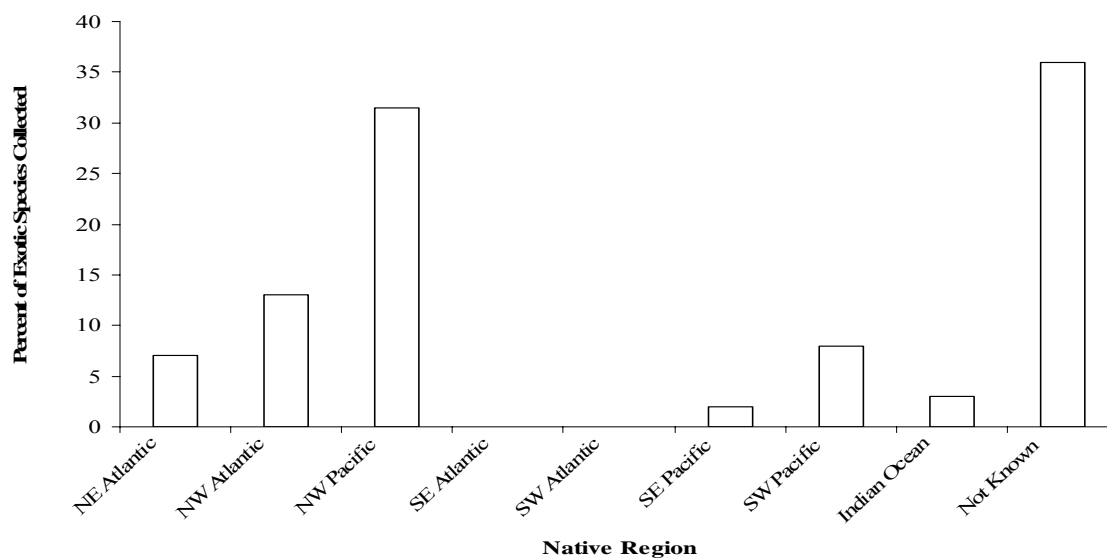
Table 7. Origins, earliest records and mechanisms of introduction

(page 3 of 3)

Species	Native Range	First Pacific Coast Record	First Southern California Record	Mechanism of Introduction
<u>Urochordata</u>				
<i>Ascidia</i> sp. A	not known	1983	1983	BW,SF
<i>Ascidia zara</i>	NW Pacific	1984	1984	BW,SF
<i>Botrylloides violaceus</i>	NW Pacific	1973	2000?	OJ,SF
<i>Botryllus firmus</i>	?	2000?	2000?	BW,SF
<i>Botryllus schlosseri</i>	NE Atlantic	1944-47	1965	OA,SF
<i>Botryllus</i> sp. A	not known	2000	2000	BW,SF
<i>Ciona intestinalis</i>	NE Atlantic	1897	1917	SF
<i>Ciona savignyi</i>	NW Pacific	1903	1985	BW,SF
<i>Microcosmus squamiger</i>	SW Pacific	1986	1986	BW,SF
<i>Molgula manhattensis</i>	NW Atlantic	1949	1984	OA,SF,BW
<i>Polyandrocarpa zorritensis</i>	SE Pacific	1994	1994	BW,SF
<i>Styela canopus</i>	NW Atlantic	1945	1972	SF,BW
<i>Styela clava</i>	NW Pacific	1932-33	1933	BW,OJ,SF
<i>Styela plicata</i>	not known	1915	1915	SF,BW
<i>Symplesma reptans</i>	NW Pacific	1997	1997	BW,SF

**Figure 5. Exotic species by native ranges**

Native ranges of the exotic species collected sorted into major oceanic regions. Where a species' range included more than one region, it was allocated proportionally between regions (e.g. a species with a native range on both sides of the North Atlantic was counted as 0.5 species with a NE Atlantic range and 0.5 species with a NW Atlantic range).



For the exotic species collected on the expedition, the dates of the first collection records on both the Pacific Coast and in southern California show spikes in the 1940s and the 1990s (Fig. 6 & 7). It is possible that these spikes result from stronger or more effective transport vectors during those periods, such as an increase in World War II-related military vessel traffic in the 1940s, and an increase in

commercial shipping and ballast water discharges from China, Japan and Korea in the 1990s. However, it is also possible that these spikes simply reflect the strength of the collecting effort during those periods, particularly collecting among taxa or in habitats that tend to harbor large numbers of exotic species. In the 1990s this would include (among many other southern California taxonomists) the work of G. and C.C. Lambert in the tunicates and of L.H. Harris in the polychaetes, as well as the current expedition.

Figure 6. Exotic species by date of first Pacific Coast record

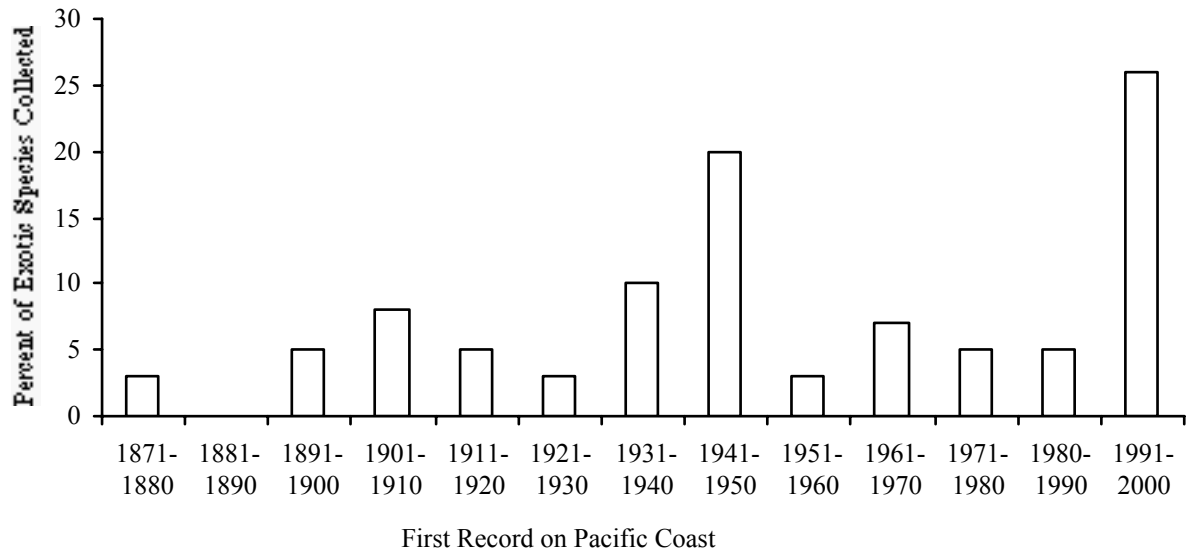
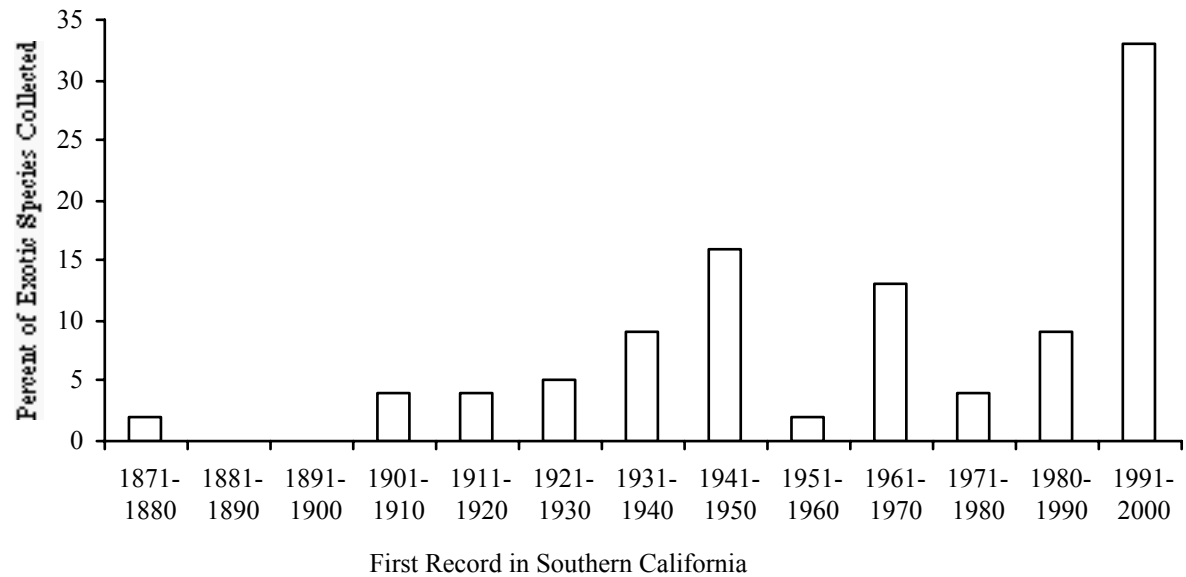


Figure 7. Exotic species by date of first Southern California record

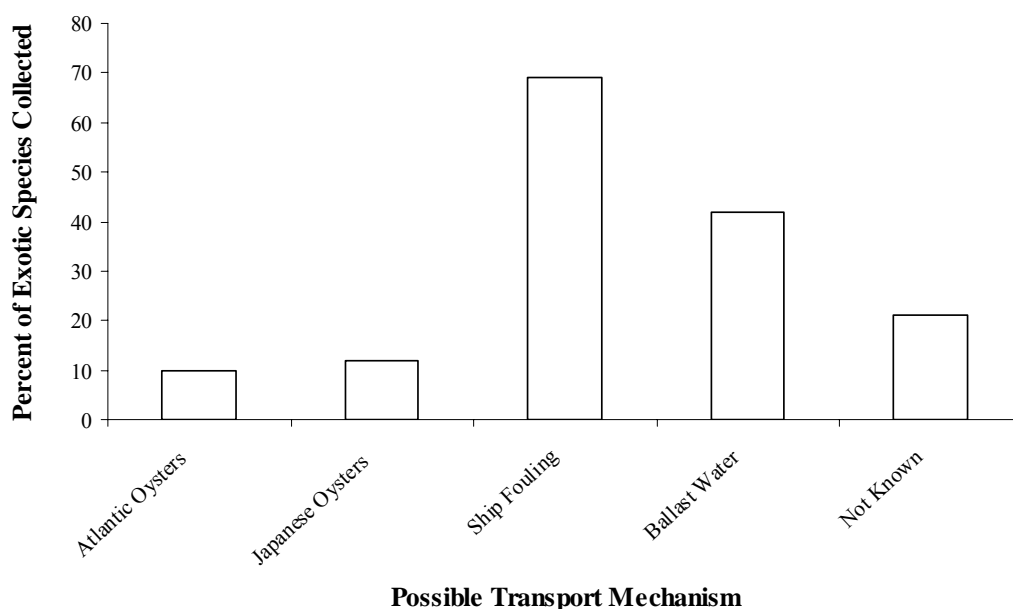


Transport as fouling organisms attached to the hulls of ships, or as wood-boring (or associated crevice-occupying) organisms in the hulls of wooden ships, is a possible vector for the transport of

two-thirds of the exotic organisms collected by the expedition (Fig. 8), an unsurprising result given that much of the collecting focussed on fouling communities on structures such as floating piers and attached or associated structures including tires, ropes, bumpers and boat hulls, and on fixed structures including pilings, bridge supports and seawalls. Ballast water discharges are a possible vector for over two-fifths of the exotic species collected. Historic imports of large quantities of oysters for commercial aquaculture, including the Virginia oyster *Crassostrea virginica* from the northwestern Atlantic and the Pacific oyster *Crassostrea gigas* from Japan, are each a possible vector for about a tenth of the exotic species collected, which aside from the oysters themselves could include a variety of organisms living in or on the shells of the oysters, or in the mud or water in which the oysters were transported. *Crassostrea virginica* is not established in southern California, but the expedition collected *C. gigas* at Island Yacht Anchorage in the back portion of Los Angeles Harbor, and during a reconnaissance trip for the expedition in June 2000 we found a population of *C. gigas* growing on rocks in the back part of Agua Hedionda Lagoon. Given the locations of these populations, it is possible that they arrived in southern California by entirely different transport vectors: the Los Angeles population resulting from accidental ship-borne transport in ballast water or attached to the hull, and the Agua Hedionda population resulting from spawn escaping from an oyster-farming operation at the mouth of the lagoon.

**Figure 8. Exotic species by possible mechanisms of transport to the Pacific Coast**

In many cases more than one possible transport mechanism is listed for a species, so that the total for all species exceeds 100%. Less likely mechanisms (given in parentheses in Table 7) were not included. Mechanisms are as described in Table 7.



## **Acknowledgments**

We are grateful to the following people and institutions for their help:

The Los Angeles County Museum of Natural History (Polychaete Collection) and the San Diego Ocean Monitoring Laboratory for allowing us to use their laboratories, microscopes and other equipment; Don Cadien for taxonomic work and assistance with the scientific literature; and Leslie Harris for opening her house and providing lodging for the expedition participants and for myriad other forms of assistance. We thank the State Water Resources Control Board, the California Department of Fish and Game, and the National Fish and Wildlife Foundation for providing financial support for this research.

## Literature Cited

- Carlton, J.T. 1979. *History, Biogeography and Ecology of the Introduced Marine and Estuarine Invertebrates of the Pacific Coast of North America*. Ph. D. thesis, University of California, Davis CA.
- Cohen, A.N. and J.T. Carlton. 1995. *Biological Report. Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta*. A Report for the U.S. Fish and Wildlife Service, Washington, DC and The National Sea Grant College Program, Connecticut Sea Grant, NTIS Report Number PB96-166525.
- Cohen, A.N. and J.T. Carlton. 1997. Transoceanic transport mechanisms: The introduction of the Chinese mitten crab *Eriocheir sinensis* to California. *Pac. Sci.* 51(1): 1-11, 1997.
- Cohen, A.N., C.E. Mills, H. Berry, M.J. Wonham, B. Bingham, B. Bookheim, J.T. Carlton, J.W. Chapman, J.R. Cordell, L.H. Harris, T. Klinger, A. Kohn, C.C. Lambert, G. Lambert, K. Li, D. Secord and J. Toft. 1998. *Report of the Puget Sound Expedition, September 8-16, 1998; A Rapid Assessment Survey of Nonindigenous Species in the Shallow Waters of Puget Sound*. For the Washington State Department of Natural Resources, Olympia, WA and the United States Fish and Wildlife Service, Lacey, WA.
- Cohen, A.N., H. Berry, C. Mills, D. Milne, K. Britton-Simmons, M. Wonham, D. Secord, J.A. Barkas, B. Bingham, B. Bookheim, J. Byers, J.W. Chapman, J. Cordell, B. Dumbauld, A. Fukuyama, L.H. Harris, A. Kohn, K. Li, T. Mumford, V. Radashevsky, A. Sewell, K. Welch. 2001. *Report of the Washington State Exotics Expedition 2000: A Rapid Assessment Survey of Exotic Species in the Shallow Waters of Elliot Bay, Totten and Eld Inlets, and Willapa Bay*. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia WA.
- Ditchfield, J. 1993. Cholera, plankton blooms, and ballast water. *Global Biodiversity* (Canadian Museum of Nature) 3(3): 17-18.
- Epstein, P.R., Ford, T.E. and R.R. Colwell. 1993. Marine ecosystems. *Lancet* 342: 1216-19.
- Geller, J.B. 1994. Marine biological invasions as models of dispersal: tracking secondary spread and introgressive gene flow. *CalCOFI Rep.* 35: 68-72.
- Hallegraeff, G.M. and C.J. Bolch. 1991. Transport of toxic dinoflagellate cysts via ships' ballast water. *Mar. Poll. Bull.* 22(1): 27-30.
- Hallegraeff, G.M., C.J. Bolch, J. Bryan and B. Koerbin. 1989. Microalgal spores in ship's ballast water: a danger to aquaculture. Pages 475-480 in: *Toxic Marine Phytoplankton*, E. Granéli, B. Sundström, L. Endler and D.M. Anderson (eds.), Elsevier, New York.
- Lambert, C.C. and G. Lambert. 1998. Non-indigenous ascidians in southern California harbors and marinas. *Mar. Biol.* 130: 675-688.
- McCarthy, S.A. and F.M. Khambaty. 1994. International dissemination of epidemic *Vibrio cholerae* by cargo ship ballast and other nonpotable waters. *Appl. Envi. Microbiol.* 60(7): 2597-2601.

- Mills, C.E., A.N. Cohen, H.K. Berry, M.J. Wonham, B. Bingham, B. Bookheim, J.T. Carlton, J.W. Chapman, J. Cordell, L.H. Harris, T. Klinger, A.J. Kohn, C. Lambert, G. Lambert, K. Li, D.L. Secord and J. Toft. 2000. The 1998 Puget Sound Expedition: a rapid assessment survey for nonindigenous species in the shallow waters of Puget Sound. Pages 130-138 in: Proc. First Nat'l Conf. on Marine Bioinvasions, Jan. 24-27, 1999, Cambridge MA.
- Nalepa, T.F. and D.W. Schloesser. 1993. *Zebra Mussels: Biology, Impacts, and Controls*. Lewis Publishers, Boca Raton, FL.
- O'Hara, P. 1993. Overview of the marine biotoxin crisis in 1993. Pages 3-6 in: *Marine Toxins and New Zealand Shellfish*, J.A. Jasperse (ed.), Royal Society of New Zealand, Misc. Ser. 24.
- Sarver, S.K. and D.W. Foltz. 1993. Genetic population structure of a species' complex of blue mussels (*Mytilus* spp.). *Mar. Biol.* 117: 105-112.
- Suchanek T.H., Geller, J.B., Kreiser, B.R. and Mitton, J.B. 1997. Zoogeographic distributions of the sibling species *Mytilus galloprovincialis* and *M. trossulus* (Bivalvia: Mytilidae) and their hybrids in the north Pacific. *Biol. Bull.* 193: 187-194.
- Tauxe, R.V. 1995. Epidemic cholera in the new world. *Emerging Infectious Diseases* 1: 141-146.
- Travis, J. 1996. Invader threatens Black, Azov Seas. *Science* 262: 1366-1367.
- U.S. Federal Register. 1991. 58(No. 239): 64831-64836.

## **Appendix 1. List of Participants**

Brian L. Bingham  
Western Washington University  
Bellingham WA 98225

Gretchen Lambert  
12001 11th Ave. NW  
Seattle WA 98177

Don Cadien  
Marine Biology Lab, JWPCP  
24501 S. Figueroa Street  
Carson CA 90745

John C. Ljubenkov  
Dancing Coyote Ranch  
P.O. Box 781  
Pauma Valley CA 92061

James T. Carlton  
Maritime Studies Program  
P.O. Box 6000  
Mystic CT 06355-0990

Ricardo Martinez Lara  
San Diego Ocean Monitoring Laboratory  
4918 North Harbor Drive, #101  
San Diego CA 92106

John W. Chapman  
Hatfield Marine Science Center  
Oregon State University  
2030 South Marine Science Drive  
Newport OR 97365-5296

Steven N. Murray  
California State University  
Fullerton CA 92834-6850

Andrew N. Cohen  
San Francisco Estuary Institute  
7700 Pardee Lane  
Oakland CA 94621

Linda C. Rao  
Water Quality Planning Unit  
State Water Resources Control Board  
Sacramento CA 94244

Leslie H. Harris  
Polychaete Collection Manager  
Los Angeles County Museum of  
Natural History  
900 Exposition Boulevard  
Los Angeles CA 90007

Kathleen Reardon  
c/o Maritime Studies Program  
P.O. Box 6000  
Mystic CT 06355-0990

Charles C. Lambert  
12001 11th Ave. NW  
Seattle WA 98177

Evangelina Schwindt  
Lab. de Ecologia  
Universidad Nacional de Mar del Plata  
Mar del Plata, Argentina

## Appendix 2. Expedition Schedule

### Wednesday, August 23, 2000

Assemble the team in Los Angeles

### Thursday, August 24, 2000

- |           |                          |                              |
|-----------|--------------------------|------------------------------|
| 1. SCX-17 | Cabrillo Beach Boat Ramp | Los Angeles, Los Angeles Co. |
| 2. SCX-16 | Watchorn Basin           | Los Angeles, Los Angeles Co. |
| 3. SCX-14 | Newmark's Yacht Harbor   | Los Angeles, Los Angeles Co. |
| 4. SCX-15 | Island Yacht Anchorage   | Los Angeles, Los Angeles Co. |

### Friday, August 25, 2000

- |           |  |                           |
|-----------|--|---------------------------|
| 5. SCX-21 | Jack's Landing (Cisco Sportfishing Center) | Oxnard, Ventura Co.       |
| 6. SCX-22 | Anacapa Isle Marina                        | Oxnard, Ventura Co.       |
| 7. SCX-20 | Port Hueneme Sportfishing                  | Port Hueneme, Ventura Co. |

### Saturday, August 26, 2000

- |            |   |                            |
|------------|---|----------------------------|
| 8. SCX-01  | Chula Vista Boat Ramp                   | Chula Vista, San Diego Co. |
| 9. SCX-02  | Fiddler's Cove (Navy Yacht Club Marina) | Coronado, San Diego Co.    |
| 10. SCX-03 | Shelter Island                          | San Diego, San Diego Co.   |

### Monday, August 28, 2000

- |            |   |                          |
|------------|---|--------------------------|
| 11. SCX-04 | Seaforth Landing (Mission Bay)            | San Diego, San Diego Co. |
| 12. SCX-05 | San Dieguito Lagoon                       | Del Mar, San Diego Co.   |
| 13. SCX-06 | Snug Harbor Marina (Agua Hedionda Lagoon) | Carlsbad, San Diego Co.  |
| 14. SCX-07 | Oceanside Harbor                          | Oceanside, San Diego Co. |

### Tuesday, August 29, 2000

- |            |                |                                |
|------------|----------------|--------------------------------|
| 15. SCX-19 | Marina del Rey | Los Angeles, Los Angeles Co.   |
| 16. SS-C   | Venice Lagoon  | Los Angeles, Los Angeles Co.   |
| 17. SCX-18 | King Harbor    | Redondo Beach, Los Angeles Co. |

### Wednesday, August 30, 2000

- |            |                                       |                             |
|------------|---------------------------------------|-----------------------------|
| 18. SCX-12 | Pilots' Dock at Pier F                | Long Beach, Los Angeles Co. |
| 19. SCX-11 | Downtown Long Beach Marina            | Long Beach, Los Angeles Co. |
| 20. SS-B   | Rainbow Lagoon (at Hyatt Tides Hotel) | Long Beach, Los Angeles Co. |
| 21. SCX-13 | Impound Marina (in Cerritos Channel)  | Long Beach, Los Angeles Co. |

### Thursday, August 31, 2000

- |            |   |                              |
|------------|---|------------------------------|
| 22. SCX-10 | Colorado Lagoon (on Alamitos Bay)       | Long Beach, Los Angeles Co.  |
| 23. SCX-09 | Long Beach Yacht Club (in Alamitos Bay) | Long Beach, Los Angeles Co.  |
| 24. SCX-08 | Huntington Harbor Yacht Club            | Huntington Beach, Orange Co. |
| 25. SS-A   | Huntington Harbor-Back Lagoon           | Huntington Beach, Orange Co. |

### Friday, September 1, 2000

Departure

### Appendix 3. Recent name changes for some species mentioned in this report

Current Name	Previous Name(s)*
<u>Annelida: Polychaeta</u>	
<i>Ficopomatus enigmaticus</i>	<i>Mercierella enigmatica</i>
<u>Mollusca: Bivalvia</u>	
<i>Geukensia demissa</i>	<i>Ischadium demissum</i> , <i>Arcuatula demissa</i>
<i>Musculista senhousia</i>	<i>Musculus senhousia</i>
<u>Arthropoda: Crustacea: Tanaidacea</u>	
<i>?Sinelobus stanfordi</i>	<i>Tanais</i> sp., <i>Tanais vanis</i>
<u>Bryozoa: Cheilostomata</u>	
<i>Watersipora ?subtorquata</i>	<i>Watersipora cucullata</i> , <i>Watersipora subovoidea</i>
<u>Urochordata</u>	
<i>Botrylloides violaceus</i>	<i>Botryllus aurantius</i>
<i>Styela canopus</i>	<i>Styela partita</i>

\* Includes some names used erroneously for Pacific Coast records.